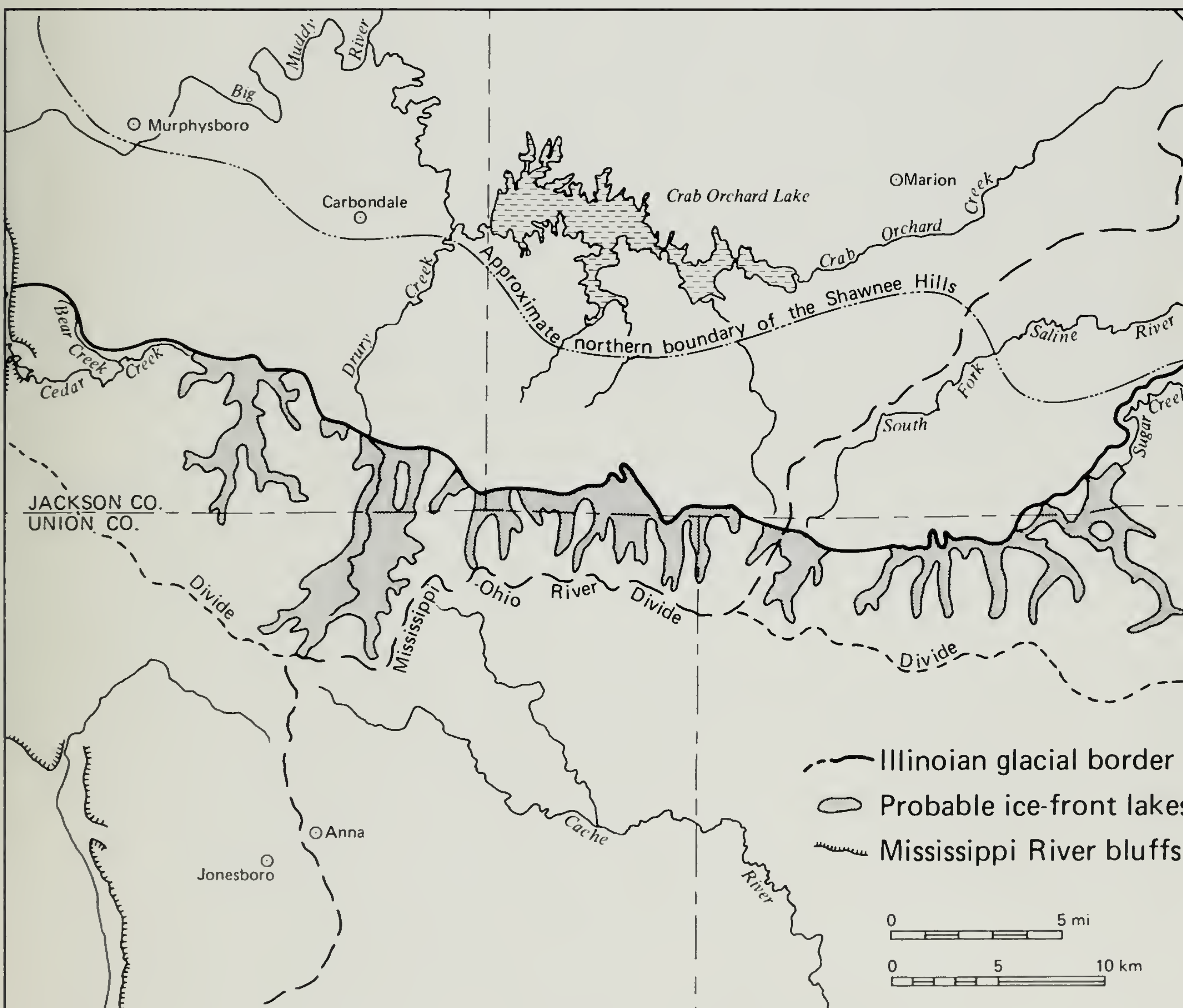
THE GLACIAL BOUNDARY IN SOUTHERN ILLINOIS

H. B. Willman and John C. Frye



Illinois Institute of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY DIVISION, URBANA, ILLINOIS
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CONTENTS

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ABSTRACT

Continental glaciation in the Northern Hemisphere reached its maximum southern extent during the Illinoian glaciation only a few miles north of the crest of the Shawnee Hills in southern Illinois. The southernmost known exposure of glacial till is near the northern boundary line of Johnson County (37° 34′ 50″ N., 88° 56′ 0″ W.). To the south of that exposure, isolated boulders in Illinois and Missouri may represent an as yet unproven older glaciation. The Illinoian glacier appears to have lost momentum and stagnated almost as soon as it mounted the northern slope of the Shawnee Hills. The thinness of the drift and the absence of depositional forms suggest rapid advance, perhaps a surge, which could account for the glacier's extending so far south. This report includes revision of the boundary of the Illinoian glaciation for several areas and maps showing many short-lived ice-front lakes that ponded in the northward-sloping valleys. The presence of an unusually high content of expandable clay minerals in the outermost drift near the Mississippi Valley is attributed to the deposition of loess on the glacier and a mixing with the drift during ablation. The presence of the Mississippi River in a narrow channel entrenched in bedrock along the western side of Fountain Bluff is attributed to diversion by a small lobe of the Illinoian glacier; however, the diversion channel probably was abandoned and reoccupied at least twice before the Holocene valley-fill reached its present level and reestablished the river in its present channel, probably in the last one to two thousand years.

INTRODUCTION

The glacial boundary across southern Illinois marks the southernmost extent of the continental ice sheet in the Northern Hemisphere during the Pleistocene glaciation. This advance of the glacier occurred during the Illinoian Stage of glaciation. At its maximum extent, the front of the glacier was only two to three miles north of the crest of the Shawnee Hills. Had it reached the crest, the glacier would have had a downgrade slope into the Mississippi Embayment Region.

The boundary of the area covered by the glacier is significant because useful deposits of sand, gravel, and clay are frequently found in, or in association with, the glacial drift. Mining and quarrying in the bedrock formations are commonly favored by the absence of a cover of glacial drift. Ground-water resources, the productivity of soils, and many engineering problems differ between the glaciated and nonglaciated regions.

In the present report, previous mapping of the border of the drift has been modified, and the characteristics and stratigraphic relations of the drift near the border, of lakes formed in valleys dammed by the glacier, and of the loess that largely mantles the border of the drift are described (fig. 1).

PREVIOUS MAPPING

The approximate position of the southern margin of the area covered by drift in Illinois was probably known to the pioneer geologists by 1850 or a little earlier. A. H. Worthen (1866, p. 27) described the distribution of the drift in Illinois: "Its southern boundary in this State appears to be the mountain chain, already mentioned, which crosses the southern portion of the State from Grand Tower on the Mississippi, to Shawneetown, on the Ohio." Worthen thought that the drift was a water-laid deposit and that the margin of the drift was determined by the "mountain chain" rising above the waters. Nevertheless, his general description of the boundary is still adequate, although the "mountain chain" is now called "Shawnee Hills" (fig. 1).

G. F. Wright (1890) traced the glacial boundary through several eastern and midwestern states and mapped the boundary in southern Illinois (fig. 2). All maps published since then have placed the boundary within about a mile of Wright's boundary in an interval of approximately 35 miles (56 km) from central Jackson County to eastern Williamson County. Differences in mapping are greater in the eastern part of Illinois, where the boundary must be projected through the broad, flat areas formerly covered by glacial Lake Saline and the Wabash Valley bottomland, and at the western edge of Illinois, where the margin of the drift is covered by thick loess. The position where the ice front entered the Mississippi Valley bottomland, which was lower than the present floodplain, is not apparent in the topography.

Frank Leverett (1899) modified Wright's mapping across southern Illinois by extending the margin southward about 10 miles (16 km) in western Saline County and near the Wabash River and by retracting it about 5 miles along the Mississippi River bluffs in Jackson County.

On the state geologic map of 1917 (De Wolf, 1917), the glacial boundary was again modified; in this revision, the boundary was incorrectly moved northward from its southernmost extent in northern Johnson County. The first detailed mapping of a segment of the boundary was by J. E. Lamar (1925), who showed the intricacy of the boundary crossing the Carbondale Quadrangle for about 15 miles (24 km). In that area, the ice front appears to have developed tongues extending up the narrow valleys eroded in the northern slope of the Shawnee Hills. Lamar also indicated the probable existence of ice-front lakes at levels high enough for overflow through the Water Valley and Cobden Cols (locations shown in figs. 6 and 7).

In the late 1930s Paul MacClintock reexamined the entire boundary in southern Illinois and described numerous exposures of drift and the position of the boundary. He prepared only a general map, and his preliminary report was not published (MacClintock, 1940). His boundary did not change the previous mapping significantly.

After extensive mapping of materials for building roads in southern Illinois, George E. Ekblaw remapped the eastern part of the glacial boundary in Saline and Gallatin Counties. On the basis of a few cobbles of igneous rocks south of Harrisburg, he projected the glacial boundary southward to the base of Cave Hill and Wildcat Hills south of Equality. Ekblaw's mapping was shown on the state geologic map of 1945 compiled by J. Marvin Weller.

In 1961 G. A. Desborough mapped the boundary of the drift in the Pomona 7.5-minute Quadrangle near the western end of the area and showed its position in greater detail than had been mapped previously.

On the 1967 state geologic map, we followed the mapping of Lamar and Desborough for the western part of the boundary but again modified the mapping of the eastern part, returning the boundary to a more northerly position, largely because we did not find the evidence cited by Ekblaw and because the hills south of Eldorado showed no indications of glaciation. This mapping was shown in more detail by Frye and others (1972).

PRESENT MAPPING

The glacial boundary in the eastern part of Illinois, in Saline and Gallatin Counties, was not restudied for the present report. The boundary along the western edge of that area has been modified slightly, and minor changes in

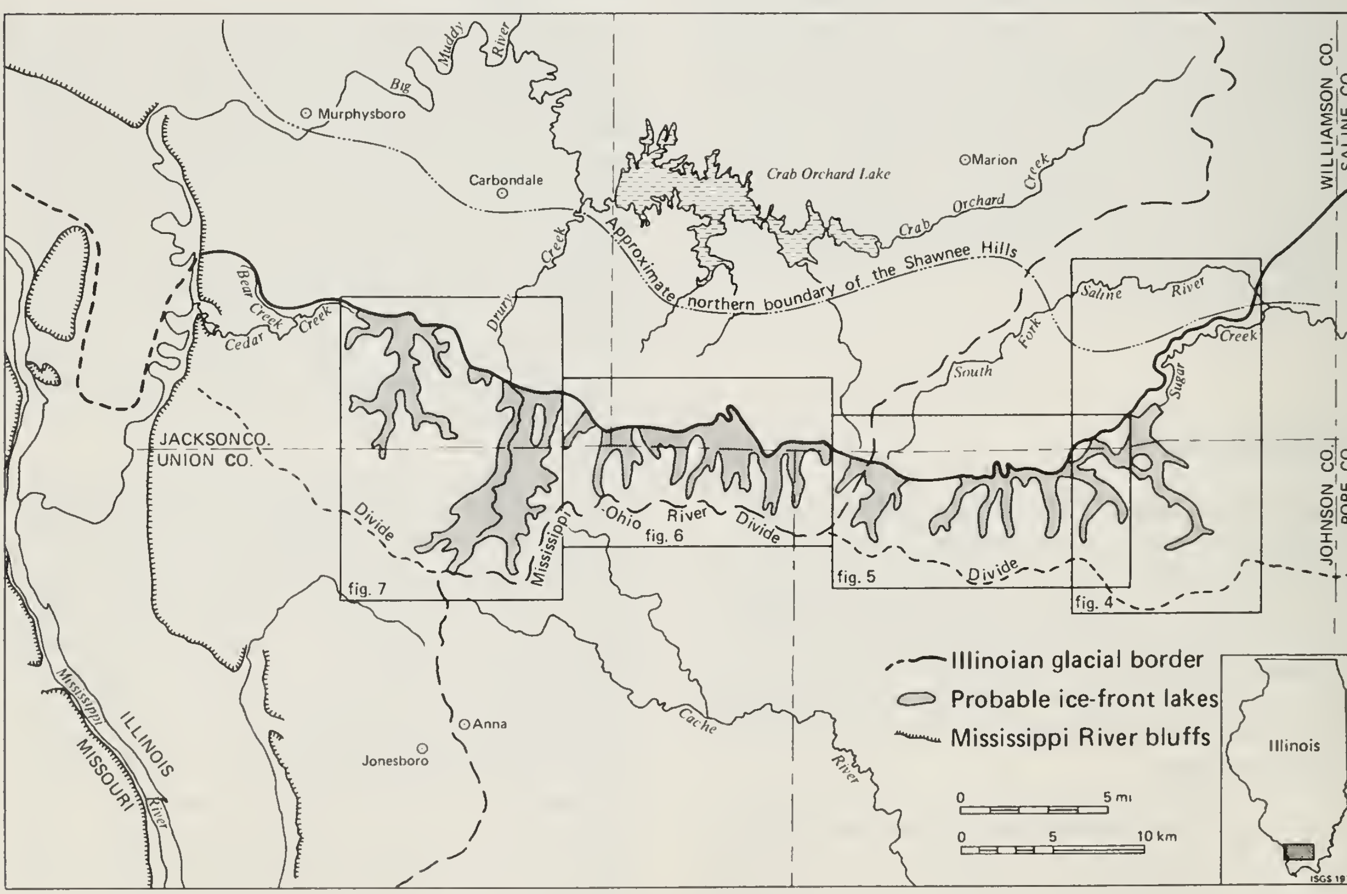

Figure 1. Illinoian glacial border, ice-front lakes, and areas shown in figures 4 through 7.

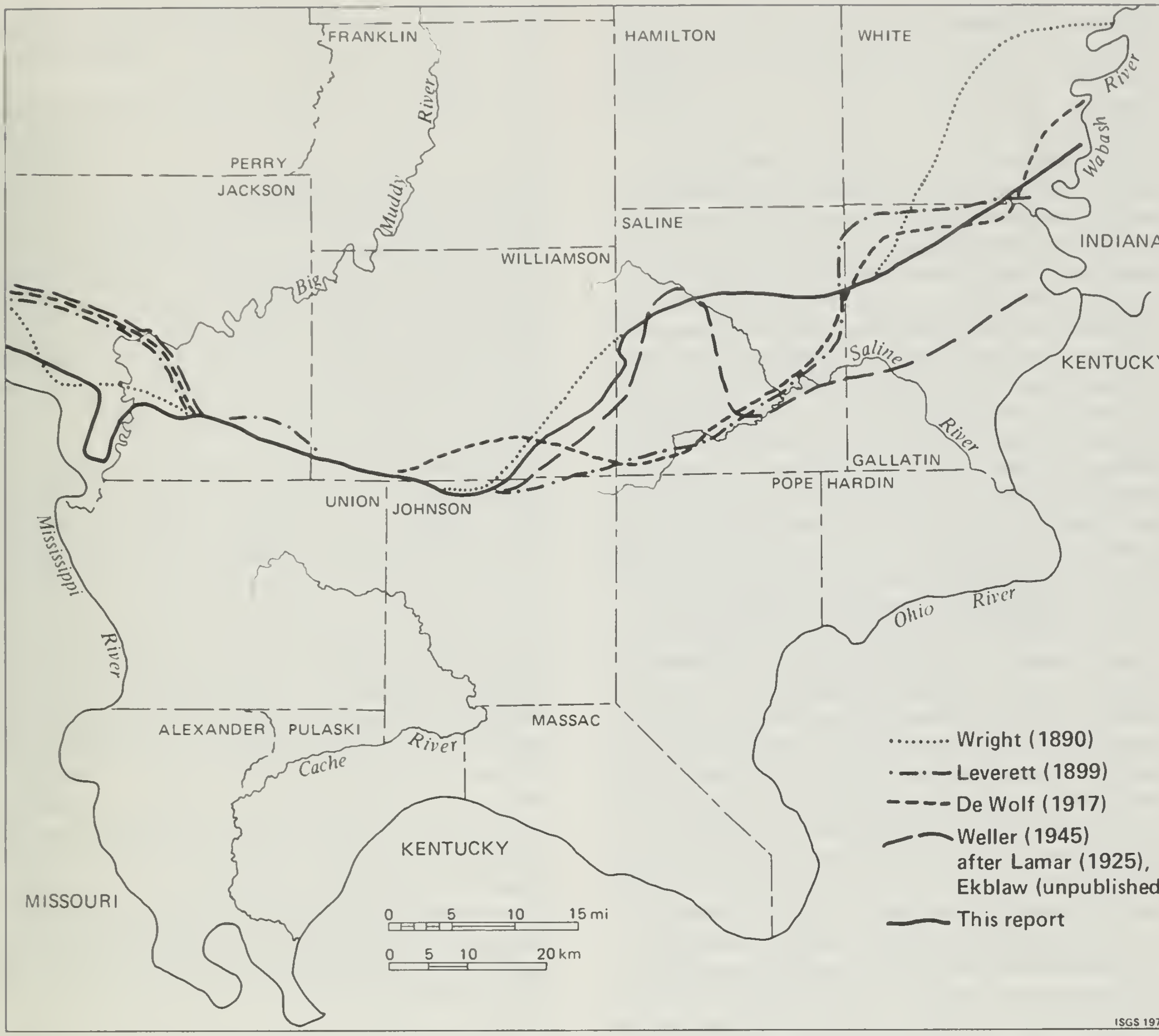

Figure 2. Generalized southern boundary of Illinoian glaciation in Illinois and previous mapping. The boundary described in this report (solid line) includes others where they are too close to differentiate.

the boundary in the central and western parts of the area have been made, largely on the basis of a few new exposures of drift, the identification of minerals in the alluvium of streams crossing or bordering the boundary, and exposures near the boundary with evidence that that locality had not been glaciated. More detailed mapping of the boundary is permitted by the greater topographic detail shown on new 7.5-minute quadrangle topographic maps that cover the entire area.

Exposures along most of the roads and in a few ravines near the boundary were examined for this study. The mapping will be improved when the new 7.5-minute quadrangle maps are geologically mapped in detail, and all the valleys, ravines, and shorelines are carefully traversed, but in many areas extensive drilling to the bedrock surface will be required to demonstrate the presence or absence of glacial drift.

New roadcuts, especially those along Interstate 57, Interstate 24, and new U.S. Highway 51 south of Carbondale gave new control on the boundary. The new cuts along Interstate 24, 2 miles (3 km) north of Goreville (geol. secs. 6, 7; app. 2), show the till, and about a quarter mile farther south they expose bedrock that probably could not have been glaciated by the Illinoian glacier. An exposure of till noted by MacClintock (1940) about 2 miles farther east and a quarter mile farther south is presently accepted as the southernmost occurrence in the Northern Hemisphere of glacial till deposited by the continental ice sheet. This occurrence, in the SW¼NE¼NE¼ Sec. 12, T. 11 S., R. 2 E., Johnson County (37° 34′ 50″ and 88°

56′ 0″) (location shown in fig. 5) is now largely buried by the waters of Lake of Egypt, but four very small ridges extending just above water level, shown on the Goreville Quadrangle map, probably consist of the drift described by MacClintock.

Sand washed from the silty alluvium along valleys that cut glacial drift is readily identified by the presence of grains of hornblende, garnet, zircon, black opaques, feldspars, and an abundance of chert. These and a variety of other minerals are abundant in the till. The sand from the alluvium in the valleys that do not have till consists largely of quartz, much of it secondarily enlarged like the sand in the Pennsylvanian sandstones. Pink quartz grains are common. Chert is rare or absent. These mineral grains can be identified readily, using only a binocular microscope, in the washed concentrate without the necessity of making grain-size or heavy-mineral separations. This technique proved particularly helpful in the areas of thick loess near the Mississippi Valley. A small exposure of till was found in a ravine a quarter mile northeast of Fairview Church (cen. W. line 31, 1S-2W, Jackson Co., Gorham Quad; see fig. 3 for location). The sand from the alluvium in that valley contains an abundance of the glacial minerals. No till was found in the ravine 1/8 mile (0.2 km) southwest of Fairview Church (SW NW SE 36, 9S-3W), but the alluvium contains a variety of glacial minerals, proportionally much less than in the previous ravine and mixed with the bedrock minerals. This indicates that at least a small amount of till underlies the loess and the slumped loess in some of the gullies heading near the Fairview School, a drainage area of about 20 acres (8 ha). A sample from a valley 0.7 mile (1.1 km) farther southwest, in the headwaters of the Little Grand Canyon (NE SW NW 1, 10S-3W), contained no glacial minerals. The same relations were useful elsewhere.

The evidence that suggests a locality was not glaciated, thus establishing a southern limit for glaciation beyond the last drift exposures, is most convincing where the Loveland Silt, the basal part of the loess succession, is present. The Loveland Silt is found only beyond the area of Illinoian glaciation, and it generally overlies a deep soil on the bedrock surface. Deep weathering of the bedrock where it is overlain by the younger Wisconsinan loesses also strongly suggests that the locality was not glaciated, but that relation is less convincing because thin till and the pre-Illinoian soil could have been eroded and a strong soil developed on the bedrock during late Illinoian, Sangamonian, and early Wisconsinan time. Nevertheless, in nearly all exposures of Illinoian till overlying bedrock, the bedrock is relatively fresh, indicating that the advancing glacier generally eroded the soil.

Problems in mapping

More precise mapping of the boundary of the glacial drift is handicapped in some areas by (1) the cover of loess or lake sediments, (2) the thinness of the drift, (3) the extensive erosion of the drift both before and after deposition of the loess, and (4) inaccessibility of some parts of the area.

Sediment cover. The major obstacle to mapping the glacial boundary accurately is burial of the boundary by younger deposits, mostly loess and lake deposits, but in some areas by river and colluvial deposits and by man-made lakes. Loess mantles almost the entire area, both the uplands and all but the steepest valley slopes. Its thickness exceeds 25 feet (7.6 m) in the area extending eastward from the Mississippi River bluffs for about 5 miles (8 km) and is slightly thinner in the immediate vicinity of the Wabash River bluffs. It thins to about 5 feet (1.5 m) in Saline and eastern Williamson Counties. As a result, a large proportion of the cuts along the roads do not completely penetrate the loess.

In Saline and Gallatin Counties, the Saline River and its many tributaries had eroded large areas north of the Shawnee Hills to such a low level that they were effectively dammed by the aggrading valley trains built in the Wabash and Ohio Valleys by outwash from the Wisconsinan glaciers. Many square miles of the Saline drainage area were covered by slackwater, called Lake Saline, in which deposits of silt and clay, commonly 10 to 20 feet (3 to 6 m) thick, locally more than 50 feet, accumulated (Frye et al., 1972). Glacial till is well exposed around the northern and western boundaries of Lake Saline, and the absence of drift between the loess and deeply weathered bedrock on several "islands" in the lake plain favors mapping the ice margin in the northern part of the lake plain. Nevertheless, the exact position of the boundary in the Lake Saline areas remains uncertain. It projects northeastward across the Wabash Valley to the glacial boundary in Indiana, but it is incongruous that the ice advanced farthest south along the slightly higher bedrock divide between the Wabash and Mississippi Valleys.

Thinness of drift. In the outer 1 to 3 miles (1 to 5 km) of the glaciated area, the drift is seldom more than 10 feet (3 m) thick. It has a patchy distribution, as shown by its absence in areas certainly covered by the glacier. North of this thinned area, the drift averages about 35 feet (11 m) in thickness, is almost continuously present except where locally eroded along valleys, and has the normal relatively flat topography of the Illinoian till plain.

The marginal drift has a recognizable glacial topography in only a few localities. In most of the area near the margin, the bedrock topography is very deeply and sharply dissected, and much of the drift, if deposited on the steep slopes, could have slumped into the valleys, where remnants of it are now buried beneath alluvium.

The thinness of the drift appears to be at least in part related to the thinness of the ice and to its dissolution by stagnation. The marginal ice may have been unusually thin as a consequence of increased resistance to flow encountered by the glacier as it advanced up the slope of the

Shawnee Hills, retarding the advance of the more heavily laden lower part of the glacier. The general absence of a terminal moraine along the boundary suggests that the glacier stagnated almost immediately on reaching its maximum extent, a common characteristic of Illinoian glaciers in other areas.

Erosion of the drift. A principal cause for the thinness of the drift in the marginal area is erosion, accelerated by the relatively high relief in that area. Throughout late Illinoian and Sangamonian time and, to a lesser extent, during and following deposition of the Wisconsinan loesses, the drift was subject to erosion, which completely removed the drift in some areas. Only erosion of the fine constituents from the till can account for those upland localities, above the level of possible lakes, where isolated pebbles, cobbles, and boulders of foreign rocks have been found. The possibility that erosion entirely removed the drift for a considerable distance south of the boundary as mapped is deemed unlikely because the loess stratigraphy and residual soils indicate that the areas south of the boundary were not glaciated by the Illinoian ice sheet.

Inaccessibility. Much of the area along the boundary is in the Shawnee National Forest, in which some roads have been abandoned and large areas are essentially inaccessible. Abandonment of old roads in part also results from the encroachment of man-made lakes that occupy many valleys.

The Fountain Bluff Diversion Channel

The mapping of the glacial boundary in the Mississippi River bottomland offers a special problem because intervals of widening, deepening, and aggrading of the valley since Illinoian time appear to have destroyed all direct evidence of what must have been a complex history.

The locality where the ice front reached the bluff near Fairview Church is fairly closely defined by exposures of till, as previously described. The Illinoian glacier appears to have crossed the Mississippi Valley to the western bluffs, which were then on the eastern side of Fountain Bluff (fig. 3), and to have diverted the Mississippi River onto the margin of the upland, where it entrenched itself in its present narrow valley west of Fountain Bluff, the Bake Oven, and the Backbone (Leighton and Brophy, 1961); however, neither till nor erratics have been found on Fountain Bluff, nor elsewhere on the western bluffs of the valley, to prove this interpretation.

The isolation also of the Bake Oven, the Backbone, and Walker Hill, south of Fountain Bluff, could be accounted for if the ice extended far enough south to block the channel between Fountain Bluff and Walker Hill, which in Illinoian time probably was the lower part of Brazeau Creek, a prominent tributary that follows the fracture zone of the Ste. Genevieve Fault in Missouri. The fault extends through this channel to the eastern bluffs at Rattlesnake Ferry. It seems likely that a lobe of the glacier would have developed in the Mississippi Valley, and it could have projected down the valley even farther than shown in figure 3.

The Mississippi River in its present course west of Fountain Bluff is essentially flowing on bedrock, but during the Illinoian glaciation the level of the valley floor in the broad expanse east of Fountain Bluff was probably considerably lower. This conclusion is based on extent of the loess of the Loveland Silt from the upland essentially to the modern floodplain and also on the absence of terraces of Illinoian age along the lower sections of tributary valleys. In these valleys, deposits of Wisconsinan terraces extend below the floodplain and apparently indicate an extensive fill since Illinoian time.

Therefore, it seems likely that the Mississippi River did not maintain its position in the diversion channel long enough for the river to cut its channel to the depth of the old channel. Consequently, following the melting of the glacier, the river abandoned the new channel and returned to its previous broad valley east of Fountain Bluff.

When the Wisconsinan valley train aggraded the Mississippi Valley to a level at least 20 to 30 feet (6 to 9 m) higher than the present floodplain, the river could have reoccupied the abandoned Illinoian channel, utilizing both channels. Evidence elsewhere indicates that after building the Wisconsinan valley train, the river entrenched itself at least 50 feet (15 m) below the present floodplain before deposition of the Holocene valley-fill began, and at that time the river could again have abandoned the channel west of Fountain Bluff. When the valley was aggraded to the present level, the river could have reoccupied the diversion channel, again utilizing both channels.

The broad floodplain east of Fountain Bluff is at essentially the same level as the floodplain of the river in its present channel, and it is subject to flooding by the river, except where prevented by man-made levees. It is now occupied normally only by the Big Muddy River, which enters the major valley from a narrow valley (fig. 3) and is essentially a meandering stream on the surface of the Mississippi floodplain. The floodplain levels are so close that the Mississippi River could have abandoned the broad valley east of Fountain Bluff only very recently, perhaps in the last one or two thousand years. The river seems to be prevented from returning to the valley east of Fountain Bluff by a low sandy area north of Fountain Bluff that is scarcely 5 feet (1.5 m) higher than the remainder of the floodplain and possibly is a remnant of a slightly older floodplain surface or a broad natural levee.

In its position along the western side of the valley for some distance to the north, the main current of the river is directed against the western side of Fountain Bluff, which was probably the major reason, before modern levees were built, that the river maintained its position through the narrow diversion channel during many flood stages.

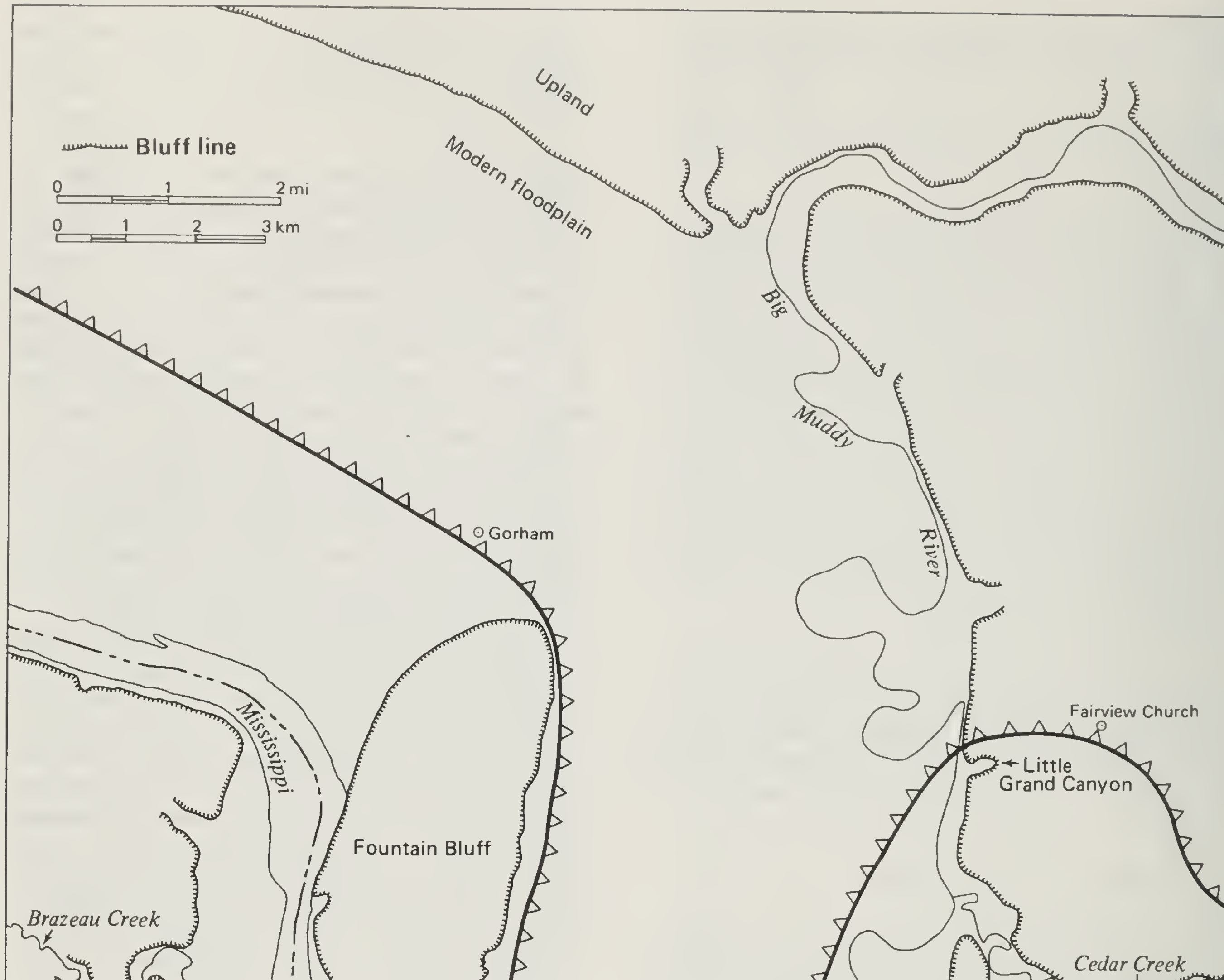

Figure 3. Diversion of the Mississippi River at Fountain Bluff.

It is not impossible that the original diversion resulted from a high level of the river during Wisconsinan glaciation that would have enabled the river to flood across a low divide into a southward-flowing tributary of Brazeau Creek west of Fountain Bluff, or perhaps even later from beheading of the tributary and capture of the river by the small stream. However, the evidence that the Illinoian glacier entered the Mississippi Valley directly east of Fountain Bluff at present favors glacial diversion as the cause for the narrow channel west of Fountain Bluff now occupied by the Mississippi River.

STRATIGRAPHIC RELATIONS

The southern boundary of the glacial drift in Illinois everywhere overlies bedrock formations of Pennsylvanian age that dip northerly into the Illinois Basin. In the western half of the area, the boundary overlies and is roughly parallel to the strike of the Caseyville and overlying Abbott Formations, which are mostly sandstone and commonly cliff forming. In the eastern half, the boundary turns more northerly into the basin and crosses successively the younger Carbondale, Modesto, and Bond Formations, which are more dominantly shaly formations that have less surface relief. The top of the bedrock is a major unconformity along which younger Pennsylvanian, Cretaceous, and Tertiary formations that are present in nearby areas are absent.

All of the drift near the border of the glaciated area is Illinoian in age and consists largely of till and local beds or lenses of lacustrine and windblown silt and outwash sand and gravel. The Illinoian drift is overlain by loess of Wisconsinan age, lake sediments, and alluvial and colluvial deposits. South of the glacial border, Illinoian deposits consist of few and small areas of sediments that were deposited in ice-front lakes and of patchy occurrences of the Loveland Silt, which is largely composed of loess and colluvial deposits resting directly on the bedrock surface and overlain by Wisconsinan loess.

PHYSIOGRAPHIC RELATIONS

The topography of the Shawnee Hills is almost entirely the result of stream erosion. The major features appear to have developed before Illinoian glaciation, but some drainage systems were diverted by glaciers, some were modified and enlarged, and many minor valleys were initiated following glaciation. Depositional glacial features are found on the northern slope of the Shawnee Hills only in a few localities—on the flatter areas near the base of the northern slope and on the floors of a few valleys occupied by tongues of ice.

Throughout the south-central part of Illinois, the northward-dipping Pennsylvanian strata are truncated by a southward-sloping surface on which a low, broad, north-south bedrock ridge diverts drainage eastward to the Wabash Valley and westward to the Mississippi Valley. This surface declines to as low as 300 feet (91 m) above sea level before it rises, in a distance of only 5 to 10 miles (8 to 16 km), to the crest of the Shawnee Hills. The crest is at the top of a prominent southward-facing escarpment capped by the resistant sandstones forming the lower part of the Pennsylvanian strata. Along the crest, a few hills are over 1,000 feet (305 m) in elevation, but generally the divide is 800 to 900 feet (244 to 274 m) with low cols around 700 feet (213 m).

For about 30 miles (48 km) east of the Mississippi Valley, the Illinoian glacier mounted the northern slope of the Shawnee Hills, rising from a level of 300 to 400 feet (91 to 122 m) at the foot of the hills to as high as 680 feet (207 m). At its highest advance, the ice front was only about 2 miles (3 km) from and 150 feet (46 m) lower than the divide between the drainage flowing northward to the Big Muddy Valley and southward to the Cache Valley. At one unusually low point in the divide, the Water Valley Col (location shown in fig. 6), the ice front was slightly less than 2 miles from the divide and crossed ridges about 75 feet (23 m) higher than the col.

The streams on the northern slope of the Shawnee Hills have a dendritic pattern, but the major valleys have a pronounced parallelism because of the steepness of the slope. The streams are sharply entrenched in the bedrock and have a local relief of 100 to 200 feet (30 to 61 m) in most areas. A maximum relief of about 400 feet in a half mile occurs at several places near the divide, and at Horton Hill in Saline County the relief is 600 feet in a little more than a mile. The valleys have narrow bottomlands which broaden to as much as a quarter mile on the lower slopes. The ridges between the valleys have less slope, but no flat upland tracts remain on the northern slope of the Shawnee Hills. The steeper slope of the inner walls of the valleys suggests a late stage of rejuvenation.

The steeper slopes of the inner walls of the valleys, the roughly concordant levels of the intervalley ridges, and the parallelism of major valleys suggest upwarping of a relatively flat erosion surface. This surface, now largely dissected, may have been inherited from the major unconformable surface on which the Mounds Gravel of the Embayment Region was deposited. The only remnant of the gravel found in the Shawnee Hills is on the top of the ridge north of Shawneetown at the extreme eastern end of the area and south of the glaciated area. The absence of the gravel elsewhere may be attributed to a lack of deposition, but the relation to the gravel in the Embayment Region suggests that a prominent erosional surface was not far above the present surface. Warping of this surface after gravel deposition, probably in early Pleistocene time, can well account for the relations found on the northern slope of the Shawnee Hills. The even greater relief on the southern slope of the Shawnee Hills resulted from the truncation

of the resistant Pennsylvanian sandstones and the more easily eroded Mississippian limestone and shale formations.

The occurrence of glacial features in the lower parts of the valleys on the Shawnee Hills indicates that the valleys had essentially reached their maximum depths before the Illinoian glacier arrived. However, the absence of drift on many glaciated surfaces, the patchy occurrence of the Loveland Silt beyond the glacial boundary, and the sharp incision of the streams into the till plain immediately north of the Shawnee Hills indicate at least strong local modification of the topography by erosion since Illinoian glaciation.

Glacial erosion was probably an insignificant factor in development of the topography. It probably smoothed the surfaces of many of the ridges between the northward-flowing streams, but the scarcity of boulders of the local bedrock in most exposures of the till suggests that there was no great amount of plucking by the ice. Near the dam of Cedar Lake (see fig. 7) the presence of large blocks of Pennsylvanian sandstone in the till indicates major erosion at the margin of the ice (J. A. Lineback, personal communication). In this locality the plunging of the ice over the north valley wall of a westward-flowing stream probably enhanced its erosive power.

CHARACTERISTICS OF THE DRIFT

Thickness

In the outer 1 to 2 miles (2 to 3 km), the drift is patchy in occurrence and rarely over 10 feet (3 m) thick. It thickens perceptibly at the base of the Shawnee Hills, and 30 to 50 feet of drift is common immediately to the north, where the Illinoian drift has a characteristic, nearly flat surface. Near the drift border, Lamar (1925, fig. 19) noted an area of somewhat thicker drift, which he thought probably indicated the presence of a terminal moraine. That area has been intensely eroded and generally lacks topography indicative of a moraine, but the thicker drift could represent the lower part of a morainic tract.

Topography

Although glacial features are present on the undissected surfaces immediately north of the Shawnee Hills, very little evidence of morainic topography has been noted on the ridges and valleys in the Shawnee Hills. Perhaps the best features are preserved on the tongues of drift extending up the valleys in the Shawnee Hills. Several of these valleys are now partly occupied by artifical lakes. The shores of the lakes in a few localities fall close to the tops of the drift, and ridges on the surface of the drift form small peninsulas that stand out prominently along the branches of Lake of Egypt in the valleys of Anderson, Sugar, and Dry Fork Creeks, as shown on the Goreville Quadrangle topographic map. A few of these ridges may be landslide or erosional features, but most have a distinctly glacial appearance. A hill of drift in the valley of Grassy Creek (geol. sec. 5) and ridges just to the south of the valley, noted by Lamar (1925, p. 114) and shown on the Lick Creek Quadrangle map, may be a remnant of morainal topography. A weakly developed morainic topography is also preserved in the vicinity of Creal Springs, along Drury Creek 1 mile (1.6 km) north of Giant City State Park, and along Cedar Creek southeast of Etherton (geol. sec. 11).

Lithology

In most exposures the till is a pebbly, sandy, clayey silt. Clay is sufficiently abundant to impart a sticky plasticity when wet, and a hard compactness when dry. Pebbles are generally not abundant—less than 10 percent. Cobbles are scarce, although a few are present in most exposures, and boulders are rare. The calcareous till is gray in a few of the thicker exposures, but most of the exposed till is strongly oxidized tan and brown.

In a few localities deposits of silt separate the till from the bedrock. These deposits are similar in position to the Petersburg Silt, which is common elsewhere at the base of the Illinoian drift (geol. sec. 6). It includes well-bedded water-laid deposits and massive silts, some of which are probably loess, equivalent to the Loveland Silt found outside the area covered by drift.

The lithology of the drift in the Carbondale Quadrangle has been described in detail by Lamar (1925, p. 116-123), who noted numerous sections having interbedded lenses of silt and gravel. He also noted that boulders of dark igneous rocks were relatively more abundant in the western part of the area than in the east.

Mineral composition

Two distinctly different clay-mineral compositions are recognized in the tills along the border of the drift (table 1). At the eastern end of the area, the till samples are relatively high in kaolinite and illite; 12 samples average 25 percent expandables, 45 percent illite, and 30 percent kaolinite and chlorite. These include samples near Galatia and Omaha in the area of Lake Saline (Frye et al., 1972, table 2, p. 30). In the western part of the area, the till close to the margin of the drift is lower in kaolinite and higher in expandables; 10 samples average 45 percent expandables, 40 percent illite, and 15 percent kaolinite and chlorite.

In one exposure (geol. sec. 5) both compositions are present; the till with higher kaolinite content is at the base. In exposures near the Pulleys Mill exit of Interstate 57 (geol. secs. 2, 3), the samples from the southern exposures, nearest the ice margin, are of the low-kaolinite type; those a mile farther north are of the high-kaolinite type. The southern exposure is immediately below the loess in a high

area, whereas the northern exposure is from a stream cut 50 feet (15 m) lower, well below the upland level, and the high-kaolinite till may underlie the till with the lower kaolinite content. In a boring at Carbondale, the bulk of the till has the high-kaolinite composition, and only the upper few feet have the low-kaolinite composition (H. D. Glass, personal communication).

The high-kaolinite till, therefore, is probably the basal till. The low-kaolinite till dominates in the shallow exposures close to the margin, except east of the Pulleys Mill exposures (geol. secs. 3, 6), where the high-kaolinite till extends to the margin of the drift. In an exposure at Murphysboro (geol. sec. 9) the samples of the low-kaolinite till represent about 7 feet (2 m) of till, and along Cedar Creek near the Mississippi Valley (geol. sec. 11), directly on the margin of the drift, the samples represent 10 to 15 feet (3 to 4.5 m) of low-kaolinite till. In all other localities the samples of low-kaolinite till represent only the upper 1 to 3 feet (0.3 to 1 m) of till.

Weathering

The top of the till has a strongly developed Sangamon Soil that commonly consists of 2 to 3 feet (0.6 to 1 m) of a dark reddish-brown, very clayey B horizon overlying about 5 feet (1.5 m) of leached till (geol. secs. 3, 9, 10, 11). In many exposures the till is thin and entirely leached. The calcareous till is generally strongly oxidized. In a few samples the calcite is partially leached, and in others an unusually large amount of calcite indicates the presence of secondary carbonates. In places the B horizon is strongly mottled with bright red splotches, usually accompanied by an abundance of black nodules, lenses, and streaks of manganese and iron oxides (geol. sec. 3).

Age and origin

The drift marginal to the glacial border has long been considered to be Illinoian (Leverett, 1899), largely because of the absence of any recognized major drift border in the region south of the border of Wisconsinan drift. The soil profile on the outer margin of the drift has a thickness and characteristics comparable to those of the Sangamon Soil on Illinoian drift elsewhere in Illinois. It is much less strongly developed than profiles on the Kansan drift in western Illinois and adjacent parts of Missouri and Iowa.

Because of intense erosion during Sangamonian and perhaps Yarmouthian time, preservation of very old drift on the steep northern slope of the Shawnee Hills is not likely. Kansan drift buried by Illinoian drift has not been positively identified nearer than 25 to 30 miles (40 to 48 km) north of the southern border of the drift, but remnants of an older glaciation may yet be found beneath Illinoian drift in the border area. The scattered boulders found south of the Illinoian drift in southern Illinois and southeastern Missouri (Lamar, 1925; Flint, 1941; Willman and Frye, 1970) may indicate a much older glaciation of greater extent, but it appears that the till of that glaciation, if it exists, has been almost entirely washed away or destroyed by weathering, leaving only the lag of more resistant boulders.

Recent work by others at the Illinois State Geological Survey has shown that in Clinton and Marion Counties, 60 miles (97 km) north of the drift border, drifts representing at least three substages of Illinoian glaciation are present (J. A. Lineback, personal communication). None of these tills is as high in kaolinite as the till in the border region, and at present no correlation between them is apparent; however, the ice probably reached its maximum southern extent in the Liman Substage, the earliest Illinoian substage, as it did at its maximum westward extent in western Illinois and eastern Iowa (Willman and Frye, 1970).

No evidence of weathering has been observed between the two tills with different clay-mineral compositions in the border region. Because the upper till, which has a high content of expandable clay minerals, is restricted to a narrow belt at the margin of the drift, the two tills probably do not represent separate till sheets or even local readvances of the ice front. The composition of the lower, high-kaolinite till is characteristic of much of the earliest Illinoian drift in the area where the glacier overrode Pennsylvanian sediments. The till below the Illinoian till plain immediately north of the border region, where depositional glacial features are preserved, is the high-kaolinite till.

The lower content of kaolinite in the marginal drift is perhaps related to dilution by expandable clay minerals, largely western-derived montmorillonite, but montmorillonite is not present in significant quantity in the bedrock or other drift formations overridden by the glacier. In some regions in Illinois where the glacier overrode thick loess deposits that are derived from western sources, a high content of expandables occurs in the lower part of the till, but in the Shawnee Hills area the upper till has the higher content of expandable minerals.

It seems possible, therefore, that the marginal part of the Illinoian glacier was covered by loess having a high percentage of expandables, which was the continuation of the Loveland Loess then accumulating beyond the glacier. The loess could have become mixed with ablation materials on the thinning margin of the stagnant ice. This would account for the complete change in composition at the margin, where the loess would have been thickest and the ice thinnest. The relatively small quantity of the till with the expandable clay minerals and its absence in the eastern region, farthest from the source of the loess in the Mississippi Valley, support this interpretation.

The concept that the Illinoian glacier dissipated by stagnation soon after reaching its maximum extent is supported by the general absence of glacial landforms on the outermost part of the drift, the short life of the frontal lakes, and the abrupt termination of the ice advance when

it encountered the northern slope of the Shawnee Hills. The general smoothness of much of the Illinoian surface, however, differs from that of other areas of stagnation which have abundant water-deposited features related to melting ice blocks (Jacobs and Lineback, 1969). The southernmost Illinoian ice, therefore, may have been unusually thin, and it melted too rapidly to develop distinctive stagnation features. This evidence favors a rapid advance, perhaps a surge, which would account for the glacier's advancing unusually far south.

CHARACTERISTICS OF THE LOESS

Distribution and thickness

Except where it has been eroded along valleys, loess covers the drift north of the glacial boundary and the bedrock south of the boundary. Where deposited on relatively flat surfaces and protected from erosion, the loess thins progressively back from its source areas in the Mississippi, Wabash, and Ohio Valleys. The loess is as much as 100 feet (30 m) thick at a few places on the Mississippi bluffs, but 50 feet is more common. It thins eastward to about 25 feet in 5 miles (8 km), 12 feet in 10 miles, and 8 feet in 15 miles. It is as thin as 4 to 5 feet where the glacial boundary turns northward in southeastern Williamson County (fig. 2). North of there, the loess continues to be 4 to 5 feet thick for about 20 miles. Where the border of the drift turns easterly, the loess begins to thicken, and it reaches about 15 feet on the Wabash Valley bluffs at New Haven. In much of the area near the Wabash Valley, the boundary is covered by the sediments of Lake Saline rather than by loess.

Although loess is the surface material on nearly all slopes, sheetwash and slumping on many of the steeper slopes has concentrated the silt into thick accumulations on the lower slopes. The dominant material in the floodplain sediments in the valleys is silt derived from erosion of the loess.

Because the dominant winds are westerly, silt blown from the Mississippi Valley forms the bulk of the loess to within 15 to 20 miles (24 to 32 km) of the Wabash Valley, which then becomes the major source of the loess (Glass et al., 1968).

Stratigraphy

Two loesses are present in many exposures. An upper tan to light-brown silt is the Peoria Loess, and the underlying dark-brown, more clayey silt is the Roxana Silt, which is dominantly loess in this area. The Roxana Silt commonly forms the lower one-fourth to one-third of the total loess, but it is not present in some localities. Both loesses are calcareous in the thick section on the Mississippi bluffs, but the Roxana Silt becomes noncalcareous in a short distance, generally less than a mile back from the bluffs. The lower part of the Peoria Loess is calcareous for roughly 8 to 10 miles (13 to 16 km) back from the bluffs, but where the total loess is less than 10 to 15 feet (3 to 4.5 m) thick, the carbonates are leached from the entire loess section; some exceptions are near the Mississippi bluffs, where the upper leached zone has been thinned by erosion. The characteristics of the loesses are described in many of the geologic sections (app. 2).

A third loess, the Loveland Silt, which was deposited largely during the advance of the Illinoian glacier, underlies the Roxana Silt outside the area covered by the glacier. The Loveland Silt was intensely weathered to a red or reddish-brown clayey silt with a very clayey B horizon (the Sangamon Soil) comparable to that on the Illinoian drift. The Loveland overlies deeply weathered bedrock, generally a red clayey rubble of Pennsylvanian sandstone (geol. secs. 4, 6), but it overlies a clayey residuum on shale in some exposures (geol. sec. 1).

The Loveland Silt was extensively eroded and entirely removed in large areas. At its maximum development in the Mississippi bluffs, the Loveland appears to have been much thinner than the Wisconsinan loesses and probably was not over 10 to 15 feet (3 to 4.5 m) thick. Therefore, it may not have been over a foot or two thick along most of the glacial boundary, which would account for its extensive removal by erosion.

The Loveland Silt, which has a well-developed red Sangamon profile, is about 1.5 feet (0.5 m) thick along U.S. Highway 51 in Union County, a short distance south of the Jackson County line (SW SE NE 5, 11S-1W, Makanda Quad.). About 1.5 feet of strongly weathered silt, probably Loveland, is exposed in a roadcut southwest of Creal Springs (SE NW SW 3, 11S-5E, Johnson Co., Creal Springs Quad.).

The loesses are not well exposed in the Mississippi bluffs near the glacial boundary, but they probably are similar to those exposed a few miles south of the boundary at Gale in Alexander County (Frye and Willman, 1960, p. 13; Frye, Glass, and Willman, 1962). The thickness and composition of the loess in southern Illinois has been described also by Fehrenbacher and others (1965).

GLACIAL LAKES

The Illinoian glacier advancing southward up the slope of the Shawnee Hills blocked the northward-flowing streams, and many lakes were formed in the sharply incised valleys (fig. 1). Stratified silt overlain by till in several valleys indicates the existence of lakes in the valleys before the ice reached its maximum extent, and similar silts over till indicate that the lakes extended down the valleys as the ice front melted back.

Water-laid deposits of sand, silt, and clay in a few localities indicate the presence of lakes in the valleys

beyond the maximum extent of the glacier, but such deposits would have been easily eroded, and they seem to have been generally washed out of the valleys since the ice melted. Other remnants of lake sediments are probably present but buried by the loess or by the waters of three large man-made lakes.

The possible maximum extent of the lakes dammed by the glacier is based on the assumption that the position of the ice front is correctly mapped and that the lowest outlet channel, either across divides or along the ice front, controlled the maximum level of the lakes. Because of the steep slopes of most of the valley walls, the lakes could have had maximum levels much lower than indicated without significantly changing the areas covered by the lakes.

Of the outlets thus predicated, only the outlet of the easternmost lake to Maple Branch (fig. 4) has walls that strongly suggest erosion by water flowing through it. The Water Valley and Cobden Cols could have been outlets, but lack definitive characteristics, particularly erosional features that should distinguish the spillway ravines from the normal erosional characteristics of other nearby ravines. The other outlets, along the ice front between lakes, are even less distinctive, and the topography does not indicate their precise location, which on the sloping divides would be sensitive to the precise margin of the ice.

The volume of meltwater may not have been large, because the ice may have been relatively thin and because stagnation, soon after reaching the maximum extent, would have limited the contribution of water to melting of the ice in the outer few miles of the glacier. This suggests a brief interval of maximum supply of water to the lakes, temporary existence of a high-level stage, little discharge of water through the outlets, and thin sediments in the lakes. The lakes probably had unstable levels, because no shoreline features have been found. The absence of these features is understandable because of the intensity of erosion in the area of high relief during the more than one hundred thousand years between the end of Illinoian glaciation and deposition of the cover of Wisconsinan loess.

The absence of well-defined outlets suggests that much of the meltwater and rainfall in the catchment basins escaped back northward beneath the glacier. The drainage from the eastern lakes would eventually have reached the margin of the ice along the South Fork Saline River in Williamson County and that from the western lakes would have reached the margin of the ice along Big Muddy Valley in the Mississippi Valley near Fountain Bluff (fig. 1).

Some of the lakes may have drained entirely through subglacial channels, particularly during the declining stages when the water level was below any possible discharge across the surrounding ridges. Nevertheless, lakes very likely occurred in all the northward-flowing valleys blocked by the ice, at least during the advancing stage when maintence of lengthy subglacial channels would have been difficult, but it is doubtful that all of them occupied areas quite as large as shown in figure 1 and figures 4 through 7.

East of the glacial lakes mapped (fig. 1), the ice front turned northward and the tributaries on the southern side of the South Fork Saline River were not blocked by the ice. A small lake may have existed in the headwaters of Brushy Creek, a southern tributary to Sugar Creek, 2 miles (3 km) east of Creal Springs (fig. 4). A lake may also have existed 2 miles farther east in the southwestward-trending valley that apparently was not quite reached by the ice, but it could have been blocked by glacial outwash at its mouth in the South Fork Valley. Both of these valleys were later flooded during Wisconsinan time by Lake Saline.

West of the glacial lakes mapped (fig. 1), the ice front extended down Cedar Creek for more than 2 miles (3 km) before turning up the tributary of Bear Creek (Desborough, 1961). Till was observed by MacClintock (1940) near the mouth of Bear Creek. A slight extension of the ice across Cedar Creek Valley, the area now mapped as alluvium, would have blocked Cave Creek and formed a lake in its valley. The Illinoian surface in the valley was probably much lower than the present surface, and Illinoian drift could have been preserved below the alluvium. If a lake was formed in Cave Creek Valley, its elevation would not have exceeded 480 feet (146 m), which is the level of a col one-third mile (0.5 km) southwest of Natural Bridge (SW SE 17, 10S-2W, Jackson Co., Pomona 7.5-minute Quad.). The low elevation of this col is attributed to a fault, as mapped by Desborough (1961). Because there is no definite evidence that Cave Creek Valley was blocked by the ice, or of lake sediments to confirm its presence, no lake was mapped in that valley.

Very small, temporary lakes may have formed along the southwestern tributaries of Bear Creek, but probably no other lakes were present in the remaining 1.5 miles (2.4 km) to the Mississippi River bluffs.

Glacial Lake Sugar

The easternmost valley clearly dammed by the Illinoian glacier was Sugar Creek Valley, which formed Lake Sugar in Williamson and Jackson Counties (fig. 4). Lake Sugar would have received meltwater from about 3 miles (5 km) of ice front, rainfall from about 22 square miles (57 km^2) of land surface, an unknown discharge from Lake Wagon to the west, and rainfall on the glacier.

As the lowest col on the southern divide is at 690 feet (210 m), 2 miles (3 km) east of Tunnel Hill, and 585 feet (178 m) on the eastern divide at New Burnside, the outlet of the lake must have been along the lower course of Sugar Creek where the bedrock surface was at an elevation as low as about 520 feet (158 m). The boundary of the lake, therefore, is drawn on the assumption that, at its maximum level, the elevation of its surface was as high as 510 to 520 feet (155 to 158 m). At that level, it would have been 20 to 25 feet (6 to 8 m) below the Maple Branch outlet

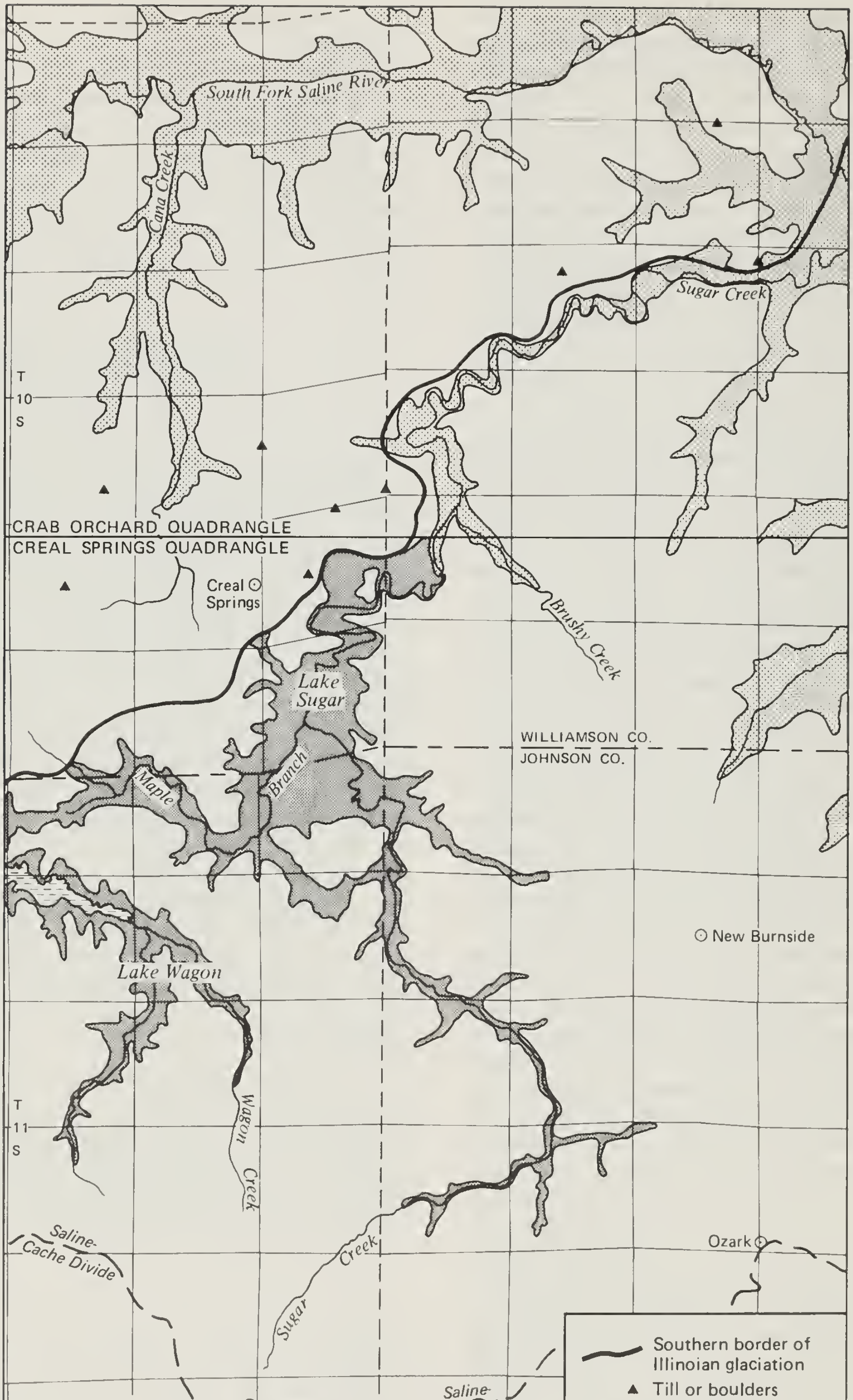

Figure 4. Glacial boundary and ice-front lakes—eastern area.

channel through which water discharged from Lake Wagon into Lake Sugar.

The most distinctive morainal front along the border of the drift is the ridge extending from near the outlet of Lake Wagon at the boundary between Williamson and Johnson Counties to Creal Springs, about 3 miles. Although this ridge may be bedrock controlled in part, its position directly across the northwestward projection of Sugar Creek blocks the probable course of Sugar Creek to the broad valley now occupied by Cana Creek, a tributary of the South Fork. Cana Creek was later occupied by Lake Saline. This diversion, if correct, requires the existence of a bedrock valley filled with as much as 100 feet (30 m) of drift at or just west of Creal Springs.

At its maximum southern extent the Illinoian glacier apparently diverted Sugar Creek northeastward along the ice front. The creek entrenched itself in a narrow, steep-walled channel in Pennsylvanian sandstone extending northeastward from just southeast of Creal Springs for about 5 miles (8 km) to the South Fork Valley. This narrow channel was eroded deeply enough to be occupied later by Lake Saline (fig. 4).

The ice front was very close to the valley, as shown by a few exposures of till; it was so close, in fact, that temporary diversions caused isolated bedrock knobs, the largest a half mile east of Creal Springs.

Exposures southeast of the diversion channel along Sugar Creek show a very clayey red soil developed on the bedrock and overlain by loess, as in a roadcut 2 miles (3 km) east of Creal Springs (cen. S. line NE NE 30, 10S-3E, Williamson County, Crab Orchard 7.5-minute Quad.). Similar soils seem to be generally lacking on the bedrock in the glaciated area northwest of Sugar Creek. The loess is relatively thin and leached in this region, and the subdivisions cannot be differentiated readily in many places. Consequently, the strong profile of weathering could be either Sangamonian or pre-Illinoian. Nevertheless, the area could not likely have been glaciated after the soil was formed, and the complete absence of even pebbles or small flakes of foreign materials in the loess or soil or on the bedrock surface strongly suggests that the Illinoian glacier did not cross the present valley of Sugar Creek.

Glacial Lake Wagon

Glacial Lake Wagon (fig. 5) existed in the headwaters of the South Fork Saline River where several long tributaries of Wagon Creek were blocked by the advancing Illinoian glacier. These tributaries are now occupied in part by Lake of Egypt, which extends 3 miles (5 km) farther northwestward within the glaciated area to a man-made dam across the South Fork. Lake Wagon extended southward from the ice front along Wagon Creek and up the tributaries of Dry Fork Creek, Sugar Creek, Anderson Creek, Beaver Creek, and the headwaters of Wagon Creek. The lake took the drainage from about 5 miles (8 km) of ice front and precipitation that fell in an area of approximately 25 square miles (65 km^2) north of the Saline-Cache divide to the ice front, and in a segment of the glacier's surface impractical to estimate.

The lake had an outlet 2.5 miles (4.0 km) southwest of Creal Springs (W½ 3, 11S-3E, Johnson County, Creal Springs 7.5-minute Quad.) to Maple Branch, a tributary of Sugar Creek, which flows into the South Fork Saline River. The outlet is at an elevation of 540 feet (165 m), almost 40 feet (12 m) above the Lake of Egypt in Wagon Creek, which is only a quarter mile (0.4 km) west of the outlet. The highest water level in the lake was probably not over 550 feet (168 m) and at that elevation it had a maximum depth of about 80 feet (24 m) at the ice front.

The generalized border of the ice, as previously drawn, although less than a half mile farther south than the present boundary, would cover the ridges between the branches of the lake considerably higher than 550 feet (168 m), requiring separate lakes in each valley except Beaver Creek and the Wagon Creek headwaters. In any case, the branches in Dry Fork Creek, Sugar Creek, and Anderson Creek would have drained westward to the same outlet. The water level would have to have reached over 700 feet (213 m) for the lake to have discharged over the southern divide to the Cache Valley, and this would require the ice front to have extended 1 to 2 miles (1.6 to 3 km) farther south along the dividing ridges in an area where no evidence of glaciation has been found. The absence of well-defined drainage channels across the divides and the absence of even foreign pebbles in exposures only a quarter to a half mile (0.4 to 0.8 km) south of the deposits of till noted by MacClintock (1940) favor the continuity of the lake at the lower level with connections in narrow channels along the tongues of ice that extended up the valleys.

The Maple Branch outlet is only about a quarter mile wide and does not appear to have been deepened more than 10 to 15 feet (3 to 4.5 m), in part because of the low gradient on the discharge side. This seems to indicate a very low discharge even for the normal precipitation in the area, and it seems likely that the outlet was not used more than a few years after the lake was filled to the 540-to-550-foot (165-to-168-m) level. This would support other evidence that the ice stagnated almost immediately after reaching its maximum extent. The rapidity with which the glacier melted back from the position is further indicated by the fact that the slightly eroded Maple Branch outlet remained the only outlet in the area east of the Big Muddy-Saline divide until the ice melted back about 5 miles (8 km) from its maximum extent and opened a discharge route along the eastward channel of the South Fork Saline River.

Such a low discharge from the lake suggests the need for alternative outlets. Evaporation would seem to have been entirely inadequate to have lowered the lake significantly in the climate of that time. The possibility that a significant volume of meltwater and rainfall drained northward under the ice along the pre-Illinoian bedrock channel

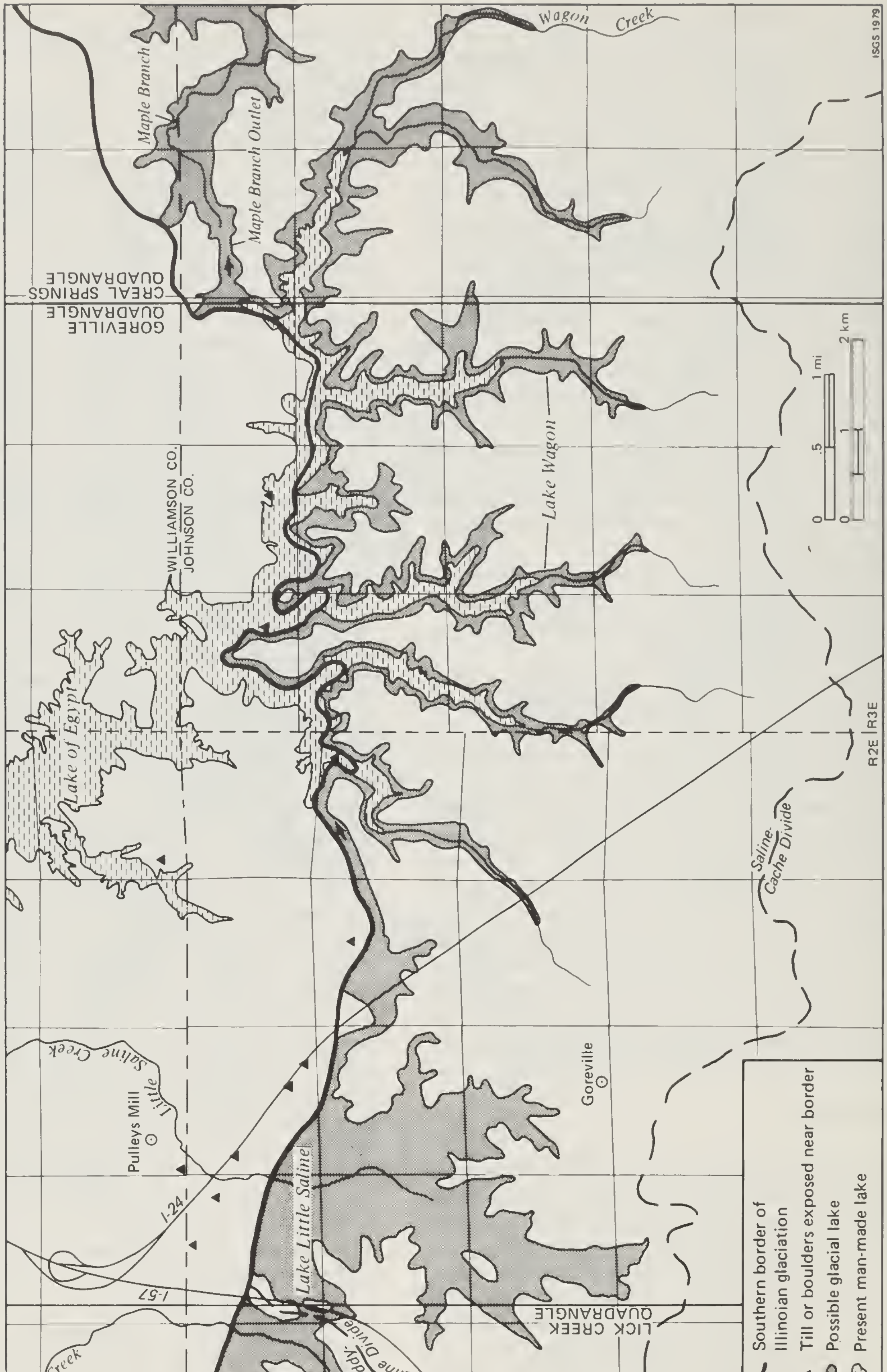

Figure 5. Glacial boundary and ice-front lakes—east-central area.

of the South Fork seems more likely. A network of subglacial channels to drain all the valleys, which are entrenched in bedrock, would have been needed. The drainage would have taken a circuitous route of 12 to 15 miles (19 to 24 km) as much as 4 miles behind the ice front before discharging at the front of the glacier where it crossed South Fork drainage near Palzo in Williamson County, only 8 miles northeast of the Maple Branch outlet of the lake. The elevation of the present South Fork Saline River is about 400 feet (122 m) at that point, but the uppermost deposits in the valley are Wisconsinan and Holocene (Lake Saline) deposits, and the Illinoian surface was somewhat lower, perhaps at the bedrock surface, which is about 375 feet (114 m). This yields a gradient of 10 to 15 feet per mile (1.9 to 2.8 m per km) from the level of the Maple Branch outlet. The gradient of the bedrock surface in this interval of the South Fork would be 5 to 7 feet per mile (0.9 to 1.3 m per km); in either case, the gradient would have been adequate to carry a significant volume of water through even a small channel. The pre-Illinoian valley is noticeably restricted by a fill of drift at several localities along the bedrock valley, and in these places discharge through subglacial channels could have been interrupted at times.

Glacial Lake Little Saline

Glacial Lake Little Saline (fig. 5) occupied the valley of Little Saline Creek in the extreme southwestern part of the Saline drainage system, separated by prominent divides from the Cache River drainage to the south and largely from the Big Muddy drainage to the west. The ice front appears to have surmounted the ridge extending northeastward from Goreville to an elevation of about 650 feet (198 m), a level at which Lake Little Saline would have discharged eastward along the ice front to Lake Wagon. Lake Little Saline would have taken the drainage from three miles of ice front and seven square miles of land surface.

A relatively low col in the Saline-Cache divide a mile southwest of Goreville (center 21, 11S-2E, Johnson County, Goreville, 7.5-minute Quad.), at an elevation of 680 feet (207 m), is marked by a steep V-shaped reentrant in the divide less than a quarter mile south of the tip of the lake, but discharge through this outlet would have required advance of the ice front about a half mile (0.8 km) farther south than presently drawn, which does not seem likely, although not impossible.

The elevation of the divide between the Saline and Big Muddy drainage is as low as 650 feet (198 m) at two places along the divide near the ice border. Consequently, a lake at that level in the valley of Wolf Creek, west of the divide, would have been continuous with the lake in the Little Saline drainage. This lake could not have drained westward because a ridge continuously over an elevation of 700 feet (213 m) separates Wolf Creek from Middle Wolf Creek. As soon as the water level fell below 650 feet (198 m), the lake would have been isolated from Lake Little Saline. Its only outlet would have been beneath the ice until the ice front retreated about 2 miles (3 km) northward, when it would have connected with a lake in the valley of Middle Wolf Creek.

The possible outlet of Lake Little Saline eastward along the ice front to Lake Wagon at a level 110 feet (34 m) lower is not marked by a clearly established channel comparable to the Maple Branch Outlet. The steep ravine through the northwest quarter of Sec. 12, T. 11 S., R. 2 E., is along the probable margin of the ice and is perhaps adequate to account for the descent of 110 feet in about a mile (21 m/km). The lake would not have lowered to the level of Lake Wagon until the ice front had retreated about 2 miles. Subglacial drainage from Lake Little Saline would have required a channel at the base of the glacier about 3.5 miles (5.6 km) long to connect with a subglacial channel carrying discharge from Lake Wagon.

Glacial Lake Panther Den

Glacial Lake Panther Den (fig. 6) existed in the headwaters of several valleys, one named Panther Den Creek, from the divide between Wolf Creek and Middle Wolf Creek to the divide between branches of Little Grassy Creek a half mile (0.8 km) east of the meeting of Jackson, Williamson, and Union Counties. Several of the valleys in that area are now occupied by Devils Kitchen Lake, which was formed by a dam across Grassy Creek, and the eastern branch of Little Grassy Lake, which was formed by a dam across Little Grassy Creek.

Meltwater and precipitation trapped in this area between the ice front and the Big Muddy-Cache Divide, 2 to 4 miles (3 to 6 km) to the south, would have come from 10 miles (16 km) of ice front and 20 square miles (52 km^2) of land surface. The lowest points in the divide are at an elevation of about 700 feet (213 m) in the eastern divide, 750 feet (229 m) in the southern divide, and 675 feet (206 m) along the ice front in the western divide. The latter, therefore, controlled the highest level for a lake along this part of the ice front. A lake at that level would have drained westward into the western branch of Little Grassy Creek, which had an outlet through the Water Valley Col at 575 feet (175 m). The possible outlet along the ice front (S½ 31, 10S-1E, Williamson County, Makanda 7.5-minute Quad.) shows no evidence of unusual deepening or scouring, and, if the lake ever attained such a level, it did so for only a very short time. At two other localities the ice appears to have crossed divides between the valleys at approximately the same elevation (575 feet [175 m]). If the lake level did not reach this height, three lakes would have existed in this area at lower levels until the ice retreated from the divides and the single lake formed at a level perhaps 100 feet (30 m) lower.

In this area, also, the possibility of a major drainage

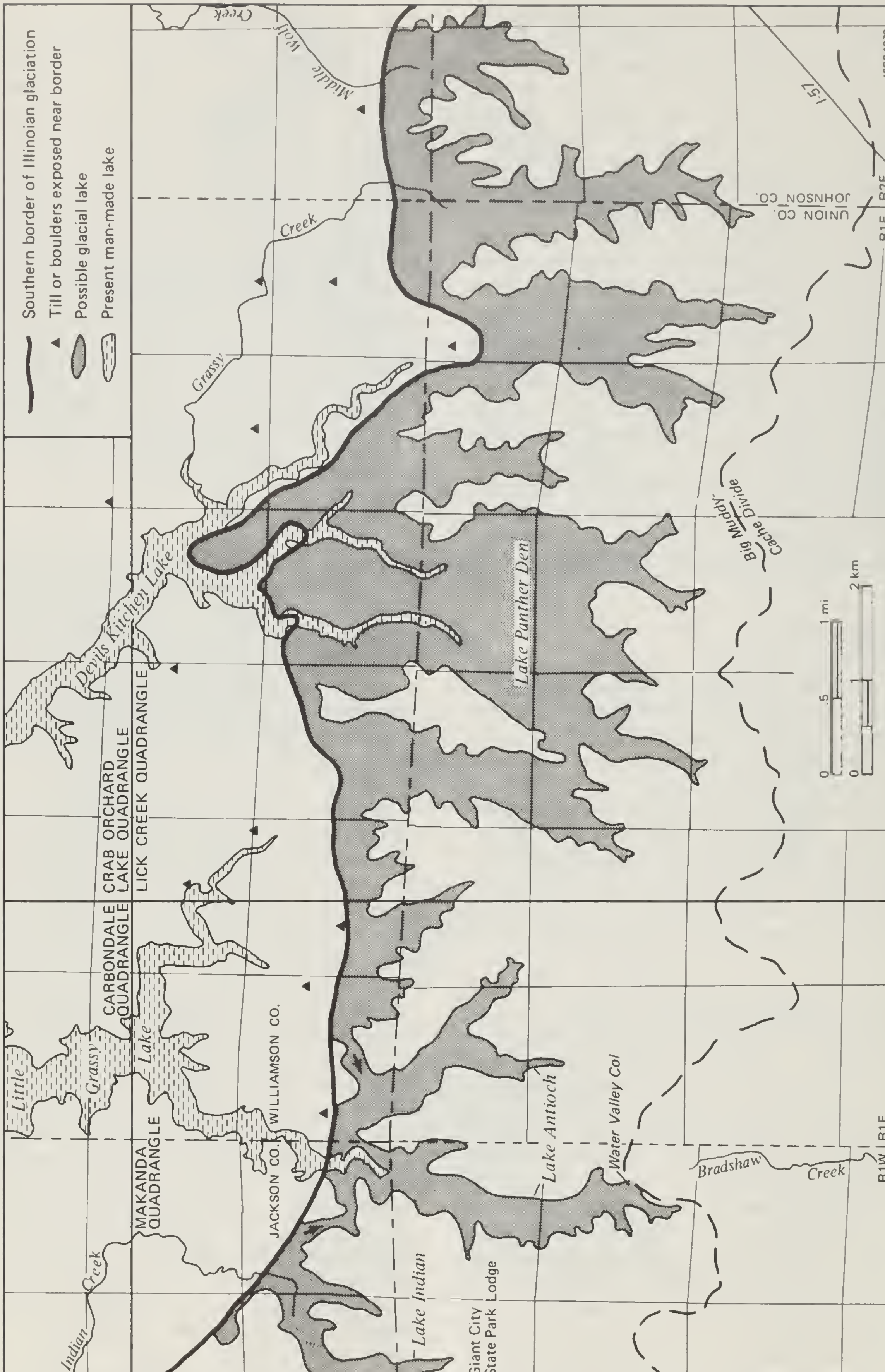

Figure 6. Glacial boundary and ice-front lakes—west-central area.

beneath the ice is favored by the lack of a definite outlet channel. If most of the meltwater and rainfall escaped beneath the ice, no single large lake would be required, but at least seven lakes would have existed at a lower level along the ice front in the area of Lake Panther Den.

Subglacial drainage would require channels along all the valleys joining a major subglacial channel along Wolf, Grassy, and Little Grassy Creeks, continuing along Crab Orchard Creek to the Big Muddy, and thence to the margin of the glacier in Mississippi Valley near Fountain Bluff, a distance of at least 30 miles (48 km), but not more than 6 miles behind the ice front. Because of the sharp pre-Illinoian relief, the subglacial channels would have to have followed at or very close to the bedrock surface in the pre-existing valleys. This seems difficult in the advancing stage and could account for very brief high-level lakes. Almost immediately after stagnation began, drainage might well have become connected through widening crevasses and around isolated ice blocks. At places the pre-glaciation Grassy Creek Valley was filled with drift, which also may have acted as a dam until outlets were cut through the drift, as in the sharply incised segments of the valley in the 2 miles (3 km) below the man-made dam forming Devils Kitchen Lake.

Glacial Lake Antioch

Glacial Lake Antioch (fig. 6) occurs in the western branch of Little Grassy Creek, now partly occupied by Little Grassy Lake. Because of an outlet through a gap in the southern divide between the Big Muddy and Cache drainage areas, it had an elevation of only 575 feet (175 m). It would have received meltwater from only 1 mile of ice front and rainfall from about 7 square miles (18 km^2) of land surface. Because of its low level, however, it could have received overflow from Lake Panther Den to the east at its maximum possible level of 675 feet (206 m) and from Lake Indian to the west at its maximum possible level of 625 feet (191 m).

The glacial lake is named for the Antioch Cemetery on the ridge between the two branches of the lake. The outlet, named the Water Valley Col by Lamar (1925), is named for the locality called Water Valley, formerly the site of a school, a mile southwest of the col. Drainage southward from the col is into Bradshaw Creek, a tributary of the Cache River, which flows into the Ohio River.

The outlet surface is flat for nearly a quarter mile (0.4 km) and slopes slightly southeast. It has the appearance of an erosional channel, but without evidence of much deepening, probably less than 20 feet (6 m). The outlet is covered with thick loess, and no bedrock outcrops, boulders, or gravel were noted. Its original low level may be related to relatively deep erosion of fractured rock along a fault, as projected by Lamar (1925).

The sand from a sample of alluvium along Bradshaw Creek 3 miles (5 km) south of the col contained none of the minerals that characterize the glacial deposits; however, they would scarcely be likely because the lake at the ice front would have been nearly 100 feet (30 m) deep and the water discharged through the Water Valley outlet would have been clear. Although definite evidence that the col was the spillway of a lake is lacking, the col may have served that purpose for a short time, as originally suggested by Lamar (1925).

The existence of Lake Antioch, perhaps at a lower level, is supported by the presence of sand and clay deposits along the west bank of Little Grassy Creek (N½ 12, 11S-1W, Union Co., Makanda 7.5-minute Quad.) at an elevation of 540 to 550 feet (165 to 168 m) (Lamar, 1925, p. 151). It would require a retreat from the maximum position of the ice front of about 1.5 miles (2 km) for Lake Antioch to have merged with the west arm of Lake Panther Den, and about 8 miles (13 km) to have merged with the remainder of Lake Panther Den, although by that distance the lake would have been reduced to a level of about 450 feet (137 m).

Lake Antioch and Lake Wagon seem to support more definitely than the other lakes the presence, at least temporarily, of high-level lakes south of the ice front. In these areas subglacial channels may not have been adequate, or were completely shut off for a longer time than in the intervening valleys.

Glacial Lake Indian

Glacial Lake Indian (fig. 6) was formed when the Illinoian ice blocked Indian Creek near the southeastern corner of Jackson County. Alluvium up the valley, only a quarter mile outside the glacial boundary, did not contain glacial material, but similar material along the creek about three-quarters of a mile below the boundary contained much glacial material.

At the maximum advance of the Illinoian glacier, Lake Indian occupied only an area about a mile long, entirely within Giant City State Park. It took meltwater from less than a mile of ice front and rainfall from about three square miles.

At the highest level, 620 feet (189 m), Lake Indian would have drained eastward along the ice front to Lake Antioch. A shallow col marks this position (SE SE NW 36, 10S-1W, Jackson Co., Makanda 7.5-minute Quad.). Probably very little water discharged through it. If none did, drainage must have been beneath the ice, because the surrounding divides are much higher.

Lake Indian would have existed in Indian Creek at a lower level until melting of the ice opened the entire valley to its junction with Drury Creek, 6 miles (10 km) north of the maximum position of the ice front, and during this stage drainage would have to have been entirely beneath the ice.

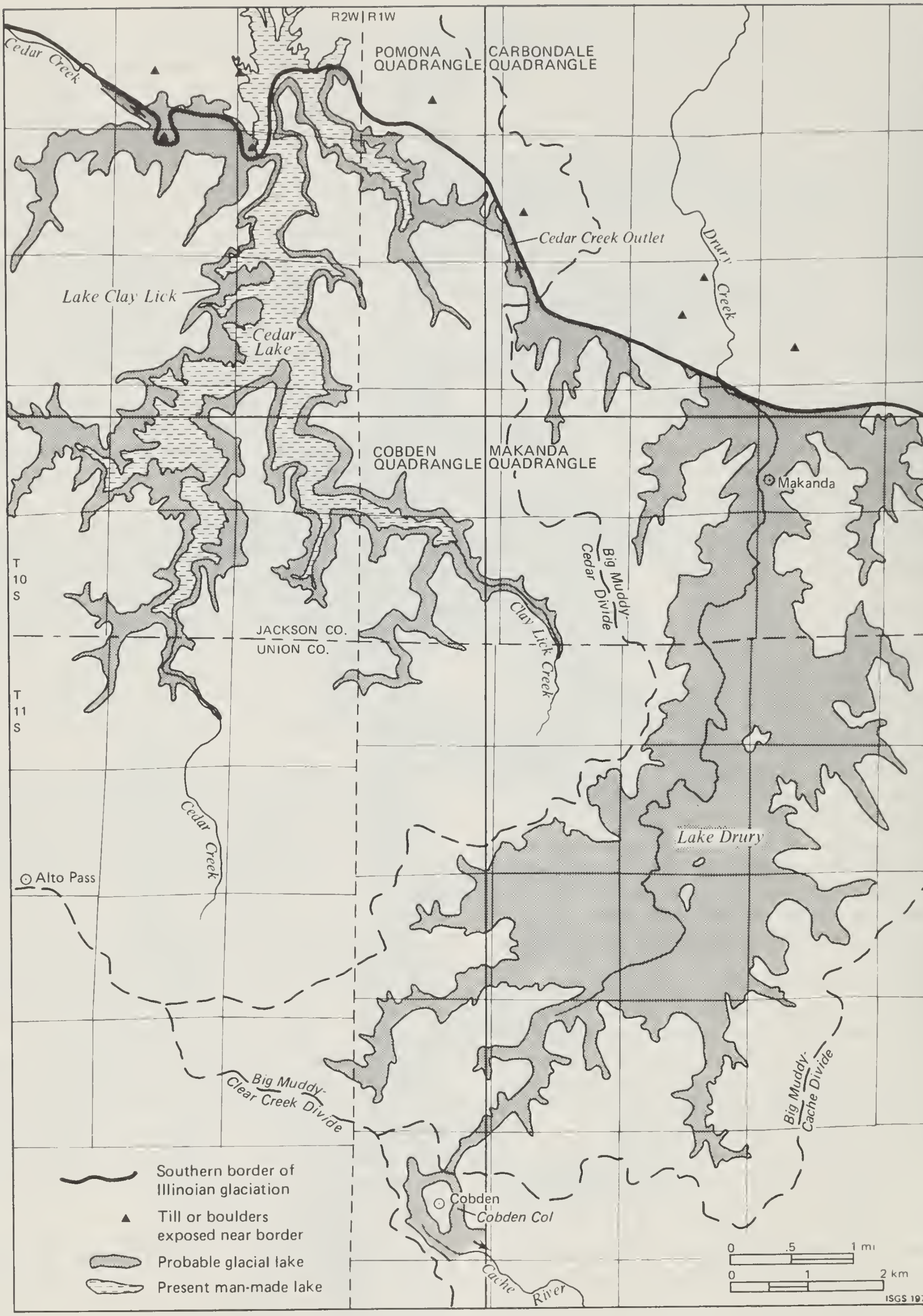

Figure 7. Glacial boundary and ice-front lakes—western area.

Glacial Lake Drury

Glacial Lake Drury (fig. 7) in Drury Creek Valley was the easternmost lake in the Big Muddy Drainage area, and it appears to have been the largest of the lakes formed along the front of the Illinoian glacier. At its maximum projected level, 600 to 605 feet (183 to 184 m), it would have covered an area approximately 6.5 miles (10 km) long from the ice front to the outlet at Cobden and about 3 miles (5 km) wide. At the ice front along Drury Creek, it would have been about 150 feet (46 m) deep. It would have carried meltwater from about 4 miles (6 km) of ice front and precipitation from 20 square miles (52 km^2) of surface beyond the ice front.

The outlet at Cobden is a long shallow col with two branches which would have isolated as an island a large part of the area occupied now by Cobden. The overflow would have been into the headwaters of the Cache River and thence to the Ohio River. The col could very well have carried discharge from the lake. The relatively low elevation of the col, like the Water Valley Col, may in considerable part be due to the presence of faults, which were mapped in that area by Lamar (1925). The thick loess cover, thicker there than farther east, prevents examination of the bedrock floor of the outlet. Well-bedded silt underlying the Roxana Loess in the area of the lake a mile northeast of Cobden (center SW 20, 11S-1W, Union Co., Makanda 7.5-minute Quad.) at an elevation of 585 feet (178 m) could have been deposited in the lake, but the silt (sample P-7772) is much less weathered than the overlying loess (samples P-7773, P-7774), and, if Illinoian in age, the Sangamon Soil must have been eroded from it before the loess was deposited.

A 2.5-foot (0.8-m) boulder of dark igneous rock on the southern bank of Cache River 3 miles (5 km) southeast of the col was interpreted by Lamar (1925, p. 151) to have been carried across the col in a floating block of ice. If icebergs carrying glacial debris were at all common on Lake Drury, glacial erratics should be common in the area of the lake, but only a few have been observed. An alternative interpretation would relate the boulder in Cache Valley to a pre-Illinoian glacier which may have transported the igneous boulders and cobbles encountered on the upland farther southwest, in Perry and Cape Girardeau Counties, Missouri (Flint, 1941). Transportation of the boulder in Cache Valley by man from the glaciated region about 10 miles (16 km) north seems less likely.

For the elevation of the lake to have been at 600 feet (183 m) the ice must have crossed Drury Creek to the upland in the southwestern part of the Carbondale Quadrangle (Secs. 20 or 21, 10S-1W, Jackson Co.). Otherwise, the lake would have had an outlet at 585 feet (178 m) (NW¼ 20, 10S-1W) along the ice front across the divide between Drury Creek and Poplar Camp Creek, a tributary of Cedar Creek, which drains directly to the Mississippi Valley (fig. 1). A slight withdrawal of the ice front would have lowered Drury Lake to that level, abandoning the Cobden outlet. If the ice did not block drainage through the Cedar Creek outlet, the maximum level of Lake Drury would have been 585 feet (178 m), at which level it would have covered nearly as large an area as indicated for the 600-foot (183-m) level.

The Cedar Creek Col, deeply mantled by loess, shows little evidence of deepening by through-flowing water, and the time it served as a spillway was probably short and the volume of water low. Otherwise, a more significant channel would have been eroded in the descent of the outlet river 185 feet (56.4 m) in about 1.3 miles (2.1 km).

As the outlets seem inadequate for the overflow of such a large lake, a considerable proportion of the drainage probably was subglacial, northward along Drury Creek to the channel of Crab Orchard Creek and thence to the Big Muddy Valley and the front of the ice in the Mississippi Valley.

A lake probably continued at a lower level in Drury Creek Valley during the retreat of the ice front about 8 miles (13 km) to Crab Orchard Creek, by which time the lower parts of Crab Orchard and Big Muddy Valleys were probably free of ice.

Glacial Lake Clay Lick

The presence of a considerable body of till at two localities on the floor of Cedar Creek Valley suggests that the glacier probably blocked the headwaters of that valley, thus forming glacial Lake Clay Lick (fig. 7), which extended up the main creek and its tributaries, including Clay Lick Creek. A large lake formed by a man-made dam across the creek (SW 12, 10S-2W, Jackson Co., Pomona 7.5-minute Quad.), is called Cedar Lake.

The elevation and extent of the lake is uncertain because it would have drained along the margin of the ice against the south wall of Cedar Creek Valley. The elevations of knobs of till on the valley floor are as high as 470 feet (143 m) and the maximum level of the lake probably would not have exceeded 500 feet (152 m). It could have been lower if much of the drainage escaped beneath the ice. This is not too unlikely because the glacier would not have had to occupy completely more than a mile of the valley floor to account for the till that still remains in the valley. The lake would have received drainage from 4 miles (6 km) of ice front and about 30 square miles (78 km^2) of land surface.

APPENDIX 1. Clay-mineral and carbonate compositions of samples.

Sample number	Geologic section	Clay minerals (%)			Carbonates (counts/sec)	
		Expandables	Illite	Chlorite and kaolinite	Calcite	Dolomite
P-2519	3	49	36	15	23	6
P-2520	3	47	38	15	-	-
P-7743	3	45	42	13	25	21
P-7744	3	45	40	15	15	?
P-7746	2	23	55	22	20	25
P-7748	2	10	74	16	30	26
P-7749	2	23	57	20	26	29
P-7754	7	36	46	18	-	15
P-7755	5	32	40	28	17	10?
P-7756	5	45	38	17	?	17
P-7776	11	43	43	14		
P-7777	11	47	40	13		
P-7779	9	45	40	15		
P-7787	10	47	34	19		
P-7796	Roadcut east side of Creal Springs, SE SE NW 25, 10S-3E, Williamson Co., Creal Springs Quad.	32	42	26		
P-7799	Roadcut one-fourth mile north of cross-roads at Dykersburg, NW NE SW 35, 10S-4E, Williamson Co., Carrier Mills Quad.	23	50	27		

NOTE: Analyses by H. D. Glass, Illinois State Geological Survey. Locations of geologic sections given in appendix 2.

APPENDIX 2. Geologic sections.

Thickness in feet

1. SAHARA NO. 5 MINE SECTION
Cutbank at edge of strip mine, west side secondary road northwest of plant, NW SW NW 29, 9S-5E, Saline Co., Carrier Mills Quad.
Pleistocene Series
Wisconsinan Stage
Peoria Loess
Silt, gray-tan, light-gray streaks along joints; surface soil at top overlain by mine spoil bank (P-7804 2 feet above base) 4
Roxana Silt
Silt, noncalcareous, brown, massive; contains some clay and a few manganese-iron pellets (P-7803 middle) 1.5
Pennsylvanian System
Carbondale Formation
Clay and silt, red to red-brown, microblocky, plastic; abundant nodules and manganese-iron streaks; Sangamon B horizon developed on shale with possibly some Loveland Silt at top (P-7802 middle) 3
Shale, gray-green, plastic (P-7801) 0.5

2. GRANGE CHURCH SECTION
Cutbank, south side tributary to Wolf Creek, NE SE NW 21, 10S-2E, Williamson Co., Marion Quad.
Pleistocene Series
Wisconsinan Stage
Peoria Loess, slumped 3
Illinoian Stage
Glasford Formation
Till, leached, rusty brown, clayey 3
Till, calcareous, light brown (P-7743 at base, less compact than below; P-7749 at top, relatively soft) 3.5
Silt, calcareous, tan, massive, compact; intertongued with till (P-7747 from silt) 1.5
Till, calcareous, blue-gray to tan, silty, massive; contains igneous cobbles to 10 inches in diameter; streaks of small pebbles are contorted; base at creek level (P-7746 at base) 5

3. PULLEYS MILL EXIT SECTION
Roadcut Illinois Highway 148, ¼ mile (0.4 km) northwest of Interstate 57, 1.5 miles (2.4 km) northwest of Pulleys Mill, SW NW NE 28, 10S-2E, Williamson Co., Goreville Quad. Described in 1966.
Pleistocene Series
Wisconsinan Stage
Peoria Loess
Silt, noncalcareous, brown (P-2526 2 feet below top in B horizon of Modern Soil; P-2525 3 feet above base; P-2524 1 foot above base) 8.5
Roxana Silt
Silt, darker brown than above; contains strong manganese-iron splotches; indistinct contact at top (P-2523 1 foot above base) 1.5

Thickness in feet

Illinoian Stage

Glasford Formation

Till, noncalcareous, silty; A horizon of Sangamon Soil (P-2522) 0.5

Till, noncalcareous, very clayey, brown to red-brown with bright red splotches; contains manganese-iron nodules, pellets, and streaks; B horizon of Sangamon Soil (P-2521). 2.5

Till, noncalcareous, tan to light brown 5

Till, silty, calcareous, gray; not very pebbly but contains igneous pebbles to 2 inches in diameter; contains secondary carbonates (P-2520 at top; P-2519 at base) 1

Another exposure of till 1 mile (1.6 km) northwest in NW SE NE 20, was sampled in 1976 (P-7743 1.5 feet below top of calcareous till; P-7744 at top of calcareous till; P-2745 leached till 1.5 feet above P-7744)

4. **HICKORY GROVE SCHOOL SECTION**

Roadcut on side road west of Interstate 57, SE NE NW 28, 10S-2E, Williamson Co., Goreville Quad.

Pleistocene Series

Wisconsinan Stage

Peoria Loess

Silt, noncalcareous, massive, gray-brown, gray and greenish tan mottled and streaked; surface soil in upper part has a dark-brown B horizon (P-7739 8 feet below top; P-7740 10 feet below top). 11

Roxana Silt

Silt, reddish brown to light brown, mottled gray-brown; indistinct platy structure; contains pebbles in lower part (P-7741 1 foot below top) 2

Illinoian Stage

Glasford Formation

Till, clayey, mottled red-brown, gray-brown, and brown; contains numerous brown clay-skins up to 2 mm thick; deeply weathered (P-7742) 0-2

Pennsylvanian System

Sandstone weathered red-tan to brownish red

5. **CHITTY CEMETERY SECTION**

Borrow pit in isolated hill on north side of Grassy Creek, SE SE SW 25, 10S-1E, Williamson Co., Lick Creek Quad.

Pleistocene Series

Illinoian Stage

Glasford Formation

Till, silty, calcareous, tan to light brown, compact; contains igneous pebbles and a 1-foot boulder (P-7755 near base; P-7756 from highest part of exposure where weakly calcareous) 10

Soil and loess eroded at top

6. **PULLEYS MILL SOUTHEAST**

Roadcut Interstate 24, 0.2 mile (0.3 km) northwest of Illinois Highway 37, NE SW SE 3, 1 mile (1.6 km) southeast of Pulleys Mill, 11S-2E, Johnson Co., Goreville Quad.

Pleistocene Series

Illinoian Stage

Glasford Formation

Thickness in feet

Till, noncalcareous, brown, compact; contains many igneous pebbles and cobbles; upper part darker and softer; Sangamon Soil B horizon not exposed and probably eroded (P-7753 1 foot above base) 10

Petersburg Silt

Silt, gray, massive but platy, compact, noncalcareous (P-7752). 4

Silt and fine sand, tan-brown, massive, compact, noncalcareous; gradation at top and bottom; contains a few small sandstone pebbles (P-7751 one foot above P-7750) 3

Pennsylvanian System

Caseyville Formation

Residuum of angular, red to red-brown sandstone pebbles and cobbles in matrix of tan silt and sand (Yarmouth Soil) (P-7750 from matrix). 2

Weathered Peoria Loess above till

7. **GOREVILLE NORTH SECTION**

Roadcut Interstate 24 at underpass of Illinois Highway 37, 2 miles north (3 km) of Goreville, SW SE SE 3, 11S-2E, Johnson Co., Goreville Quad. Southernmost exposure of till along I-24

Pleistocene Series

Illinoian Stage

Glasford Formation

Till, tan to light brown, gray-tan in lower part; contains a few rotten granite pebbles but pebbles are mostly Pennsylvanian sandstone and limonite-cemented silt; red-brown B horizon of Sangamon Soil at top is not completely exposed (P-7754 from lower part) 15

Good exposures .75 mile southeast from here and extending for 1.5 miles (2 km) show no till and Peoria Loess on moderately weathered sandstone

8. **COBDEN NORTHEAST SECTION**

Roadcut .75 mile (1.2 km) northeast of Cobden, SE NW SW 20, 11S-1W, Union Co., Makanda Quad.

Pleistocene Series

Wisconsinan Stage

Peoria Loess

Silt, gray, mottled dark gray and tan, noncalcareous, massive compact; Modern Soil at top has a clayey, tough, blocky B horizon (P-7774 4 feet above base) 7

Roxana Silt

Silt, brown, massive, noncalcareous; separated by a slumped area from the underlying beds. 2

Illinoian Stage?

Pearl Formation?

Silt, gray, bedded, noncalcareous; some thin beds are clayey, others have very fine sand; base at level of bedrock nearby (P-7772 middle). 1.5

9. **MURPHYSBORO SOUTH SECTION**

First roadcut south of Big Muddy River at Murphysboro and borrow pit 225 feet (69 m) south southeast of road, NW SW SE 8, 93-2W, Jackson Co., Pomona Quad.

Pleistocene Series

Thickness
in feet

Wisconsinan Stage

Peoria Loess

Silt, tan, compact, noncalcareous; thick B horizon of Modern Soil at top (P-7783 5 feet above P-7782). 12

Roxana Silt

Silt, brown, compact, noncalcareous; columnar structure and vertical jointing; top gradational (P-7782) 3

Illinoian Stage

Glasford Formation

Till, tan to light brown, noncalcareous, compact, massive; contains chert, quartz, and igneous pebbles; top at floor of borrow pit (P-7781 4 feet above P-7780) 6

Sand, noncalcareous, tan; contains some silt; partly slumped and thickness uncertain (P-7780) 3

Till, calcareous, gray to greenish gray, silty and clayey, moderately compact; at level of bedrock top exposed across the road (P-7779) 1

10. JONES QUARRY CREEK SECTION

Roadcut at T junction, NW SW SE 18, 9S-2W, Jackson Co., Pomona Quad.

Pleistocene Series

Illinoian Stage

Glasford Formation

Till, noncalcareous, red to red-brown, clayey, microblocky; B horizon of Sangamon Soil; top eroded (P-7789 3 feet above P-7788). 2

Till, noncalcareous, tan to light brown, massive, compact, silty and clayey (P-7788 2 feet above 7787). 3

Till, calcareous, gray-tan, clayey and silty; contains few small pebbles (P-7787) 1

11. ETHERTON SOUTHEAST SECTION

Roadcut north side Cedar Creek valley, 1.75 miles (2.8 km) southeast of Etherton, NW NE SW 11, 10S-2W, Jackson Co., Pomona Quad.

Pleistocene Series

Illinoian Stage

Glasford Formation

Till, noncalcareous, reddish tan; blocky vertical clevage; fewer pebbles than below; lower part of Sangamon B horizon which is truncated by sloping surface (P-7778 5 feet above P-7777) 2

Till, noncalcareous, gray, compact; contains more pebbles than below (P-7777 5 feet above P-7776). 5

Till, calcareous, gray, massive, compact; more clayey and more pebbly than below (P-7776 10 feet above P7775). 8

Till, calcareous, compact, gray and brown; prominent color banding; contains small pebbles (P-7775 at base). 5

Peoria Loess more than 15 feet thick is exposed in roadcuts northward up the valley slope

Desborough, George A., 1961, Geology of the Pomona Quadrangle, Illinois: Illinois State Geological Survey Circular 320, 16 p.

De Wolf, Frank W., 1917, Geologic map of Illinois (1:500,000): Illinois State Geological Survey.

Fehrenbacher, J. B., J. L. White, H. P. Ulrich, and R. T. Odell, 1965, Loess distribution in southeastern Illinois and southwestern Indiana: Soil Science Society of America Proceedings, v. 29, no. 5, p. 566-572.

Flint, Richard Foster, 1941, Ozark segment of Mississippi River: Journal of Geology, v. 49, p. 626-640.

Frye, John C., H. D. Glass, and H. B. Willman, 1962, Stratigraphy and mineralogy of the Wisconsinan loesses of Illinois: Illinois State Geological Survey Circular 334, 55 p.

Frye, John C., A. Byron Leonard, H. B. Willman, and H. D. Glass, 1972, Geology and paleontology of late Pleistocene Lake Saline, southeastern Illinois: Illinois State Geological Survey Circular 471, 44 p.

Frye, John C., and H. B. Willman, 1960, Classification of the Wisconsinan Stage in the Lake Michigan glacial lobe: Illinois State Geological Survey Circular 285, 16 p.

Frye, John C., and H. B. Willman, 1967, *in* Willman, H. B., et al., 1967, Geologic map of Illinois (1:500,000): Illinois State Geological Survey.

Glass, H. D., John C. Frye, and H. B. Willman, 1968, Clay mineral composition, a source indicator of Midwest loess: *in* The Quaternary of Illinois: University of Illinois College of Agriculture Special Publication 14, p. 35-40; Illinois State Geological Survey Reprint 1968-W, 6 p.

Jacobs, Alan M., and Jerry A. Lineback, 1969, Glacial geology of the Vandalia, Illinois, region: Illinois State Geological Survey Circular 442, 24 p.

Lamar, J. E., 1925, Geology and mineral resources of the Carbondale Quadrangle: Illinois State Geological Survey Bulletin 48, 172 p.

Leighton, M. M., and J. A. Brophy, 1961, Illinoian glaciation in Illinois: Journal of Geology, v. 69, p. 1-31.

Leverett, Frank, 1899, The Illinois glacial lobe: U.S. Geological Survey Monograph 38, 817 p.

MacClintock, Paul, 1940, The southern drift border of the Illinoian till sheet in Illinois: Illinois State Geological Survey open file.

Weller, J. M., et al., 1945, Geologic map of Illinois (1:500,000): Illinois State Geological Survey.

Willman, H. B., and John C. Frye, 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey Bulletin 94, 204 p.

Worthen, A. H., 1866, Geology: Geological Survey of Illinois, v. 1, 504 p.

Wright, George Frederick, 1890, The glacial boundary in western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois: U.S. Geological Survey Bulletin 58, 112 p.

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